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Testing the Performances of DC Series Motor Used in Electric Car

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Abstract

By using a laboratory test desk built specially to test DC Series Motor and 3-phase IM, several practical tests could be performed. This desk include the electric motor, an electronic controller and Battery Bank with a charger, enabling the practically verification of performance and behaviour of the complete electric drive system, which contains the exact parts that would be proposed to use in converting a diesel- or petrol-powered vehicle to an electric car. The resistive loads of the car were simulated using a synchronous generator with a variable electric resistive load driven by the tested motor. The tests were carried on DC Series Motor with special design and construction suitable to be used in an electric car. An electronic car foot pedal and a battery bank were used as a main source of power with a capacity suitable to a light- or medium-weight car.
The Variations of DC Series Motor rotating speed and active torque over the time were studied for these cases, when various resistive loads coupled to DC Series Motor. Some conclusions and remarks on the practical performance and behaviour of IM used in the electric car were concluded.

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*Keywords:*DC series motor; electronic inverter; electric car; batteries bank;

1. Introduction:

The purpose of this practical research is to test the performances of a special DC Series Motor used in electric cars. For this we build a laboratory desk with fully functional system including DC Series Motor, DC Controller and Battery Bank with charger, enabling to study practically the performances and behavior of the complete electric

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drive system. These parts are the exact parts that we will use in converting a petrol powered vehicle to an electric car. The tests were carried on DC Series Motor having deep slots and aluminum bars on rotor, specially constructed for use in electric cars. To perform practical tests on the complete electric drive system behavior in controlled environments, a mechanical/electrical system was built in a way that allows to change the mechanical loads on the DC Series Motor that simulate the ones that it may encounter once installed in the selected vehicle. Such loads can simulate the car running with different loads on flat roads, sloping roads, and start/run/stop running. [1], [7].

2. The laboratory testing desk:

To carry out the practical tests, a general laboratory desk was built, equipped with the following components:

- DC Series motor of suitable power and size to drive a small to medium size car.
- DC Series motor controller suitable for the size of the selected motor
- Battery bank which would be the main source of power for the tests chosen with a capacity suitable for the size of a light weight or medium size car.
- Throttle control by means of an electronic car foot pedal;
- A source of mechanical loading, chosen to be an AC electric generator with selective variable resistive loads connected to an output that converts the measured electric load into a relative mechanical load on the DC Series motor.

We conduct the practical testes using a 48V DC Series motor was chosen a DC Series motor Fig.1 having Peak Power 38 KW - Continuous Power10.5 KW - Voltage 48 V - Rotation 2850 rpm - Current 218 Amps. This DC Series motor Series motor is designed and constructed specifically to operate in the electric-traction vehicles. [2], [5], [6], [12]
To control speed of DC Motor we used Curtis Controller Model 1204-4 with operating current up to 275 Amp. This controller has 48 Volts DC supply and can handle up to 275 Amp with proper thermal cooling. Fig.2 [3]

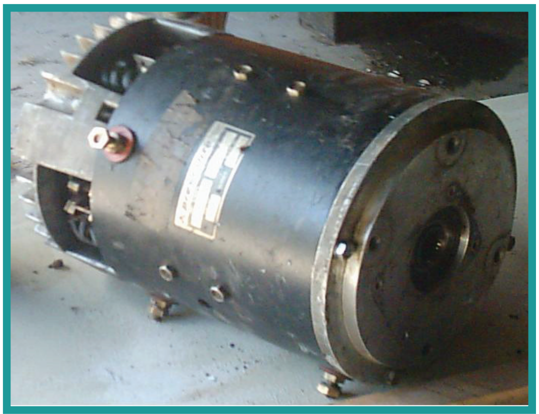
Fig 1. Tested DC SERIES motor

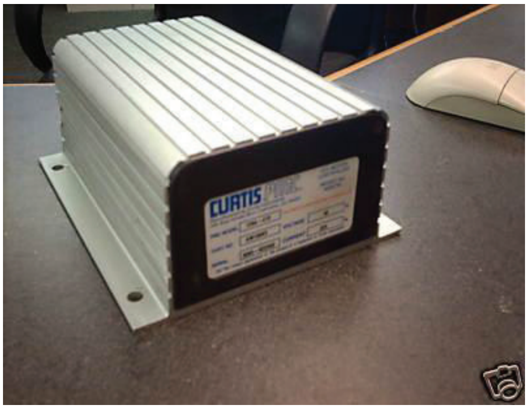

Fig 2. Used controller

WE built a battery bank using industrially available UPS grade lead-acid batteries that are designed for high current discharge. The battery bank used 2 (4 x 12) V batteries with 90Ah capacity for a total of 48Volts DC with 90 Ah capacity. Fig.3
A Throttle Controller was used to send speed control commands to controller allowing foot control. It's an industrial class foot pedal designed for electric vehicles. Fig.4 [3], [4].
The mechanical loading: based on a 32.5 KVA electric induction generator with 3-phase 380/220VAC output and 49.4 Amp current at 1500 RPM. The generator will be mechanically coupled with the electric motor. (Fig.5)

Fig.3 Battery bank

Fig 4. Foot speed pedal

Fig 5. Variable electric load

Due to the fact that DC Series Motor peaks its output at 2850 RPM, it was necessary to use a pulley system with a ratio of 2:1 to reduce the RPM to 1500 that matches the maximum for the generator. Double belt pulleys were manufactured to minimize any slip factors during the loading tests.

For the purpose of this experiment, the speed of the motor are limited to a maximum of 3000 RPM through programming the DC controller settings. The complete lab test desk is shown in Fig.6.

Fig6. the complete test lab desk

3. Testing the DC Series Motor Used in Electric Car:

It is well known that DC Series Motor can not be tested on no-load; the current of DC Series Motor can reach in this case an infinite value.
Using a 10 KW resistive load, to simulate a medium to heavy load at full throttle speed of 2850 RPM for the motor, would require 218 Amps from the battery which is equivalent to 10.5 KW; the difference from the load rating (0.5 KW) is due to the additional losses resulting from the extra torque applied on the generator, the induction generator exciting current and the losses in the induction generator and controller because of the friction, induction and heat. Increasing the load to a maximum safe value for the batteries, as this would generate huge heat at bigger resistive loads, the battery current reached a value of 447.9 Amps with a power rating of 21.5Kw.
All tests were based on a fixed rotating speed of the motor, so as to obtain results that can be interpolated in order to get behavioural charts for the integrated system, which can be used when carrying out a full implementation of the system on an actual vehicle.
According to the above tests, in addition to other similar tests that had been carried out, the abovementioned system could be a very proper candidate for the practical implementation. As the varying loads, speeds, starts and stops that a real vehicle may undergo, it's expected that the vehicle can operate for 4 hours on batteries fully charged, using two similar battery banks in parallel. This would be sufficient for a local commuter to and from work. [6], [7]

3 -1 Testing DC Series Motor to simulate running of car from standing to reach a certain speed:

This test simulate the running of DC Series Motor by applying different load torques, considering that the car weighted700 kg and the driver and 4 passengers weighted400 kg, in addition to the friction torque of the wheels on the road and the torque of the wind pressure on the car front.
This test was performed assuming that the car is in repose, and then the driver pushes his foot on the speed pedal to supply DC Series Motor with the necessary current from the batteries.
The motor will run and the car will move till reach a certain speed depending on the pedal position and the current supplied to motor. Fig.7 and shows the variation in time of the rotating speed of DC Series Motor, when a total resistive torque of 34 N.m is applied. [8].

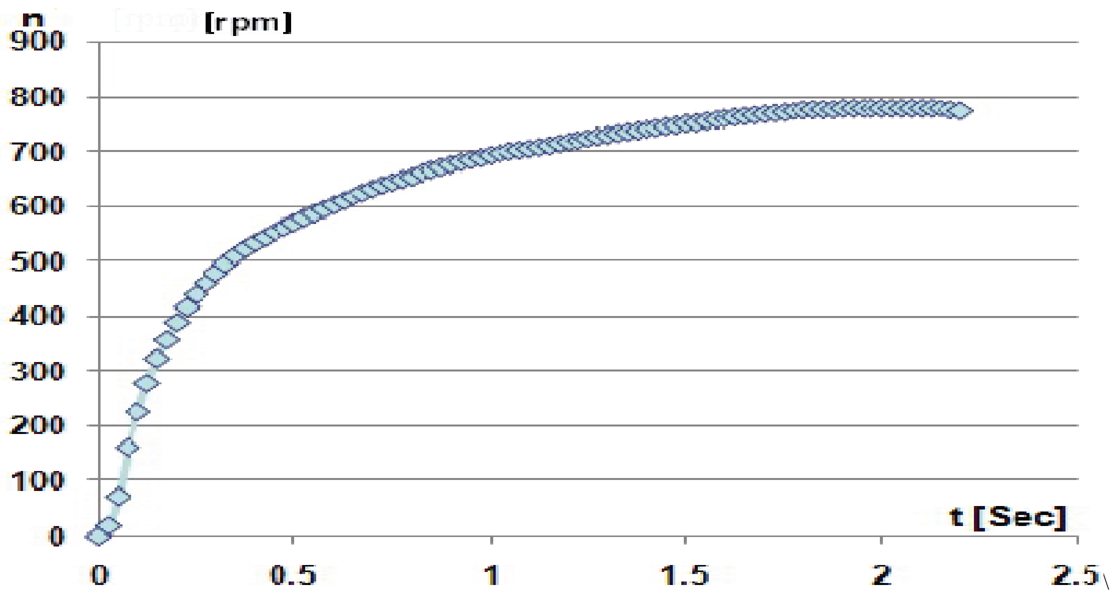

Fig.7 variation in time of rotating speed of DC Series Motor at 34 N.m resistive torques

It can be observed that rotating speed varies smoothly from 0 to 780 rpm, with a transient period of 1.8 sec.

Fig. 8 shows the variation in time of the active torque of DC Series Motor, when a total resistive torque of 34 N.m is applied. [8].

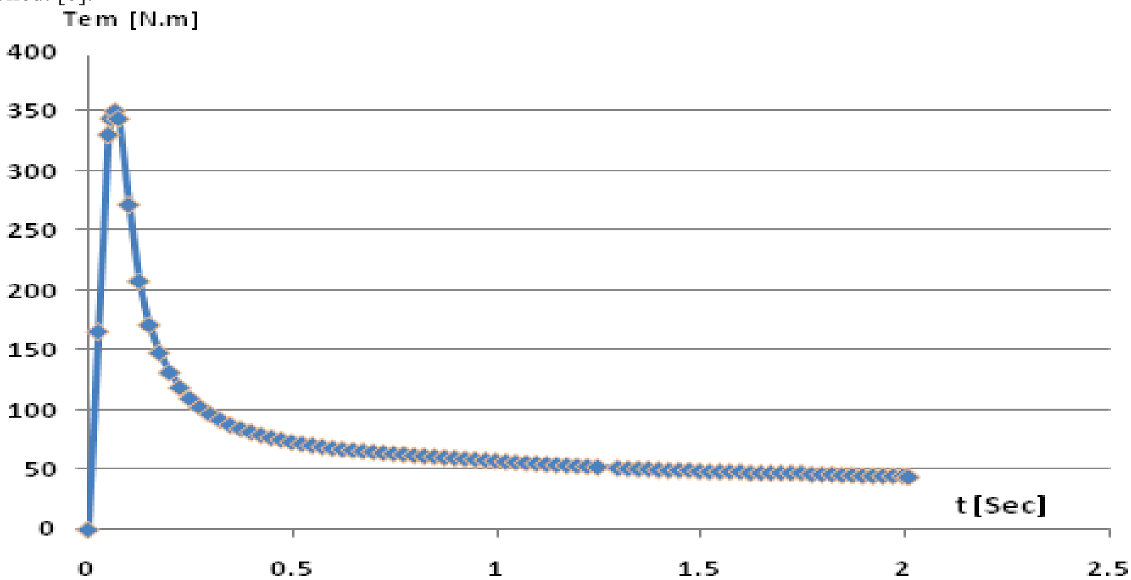

Fig.8 variation in time of active torque of DC Series Motor at 34 N.m resistive torques

It can be observed that active torque reaches a maximum starting value of 350 N.m, and stabilizes at a value of 34 N.m after a transient period of 1.7 sec.
This very high value is specific for tested 3 Phase IM used in electric car and it is a result of the special characteristics of this motor. This value is suitable in electric traction to secure the necessary force to put the electric car into motion with maximum load.
The fig.9 presents the variation of the active torque with the rotating speed of the motor, when 34 N.m resistive torques is applied.

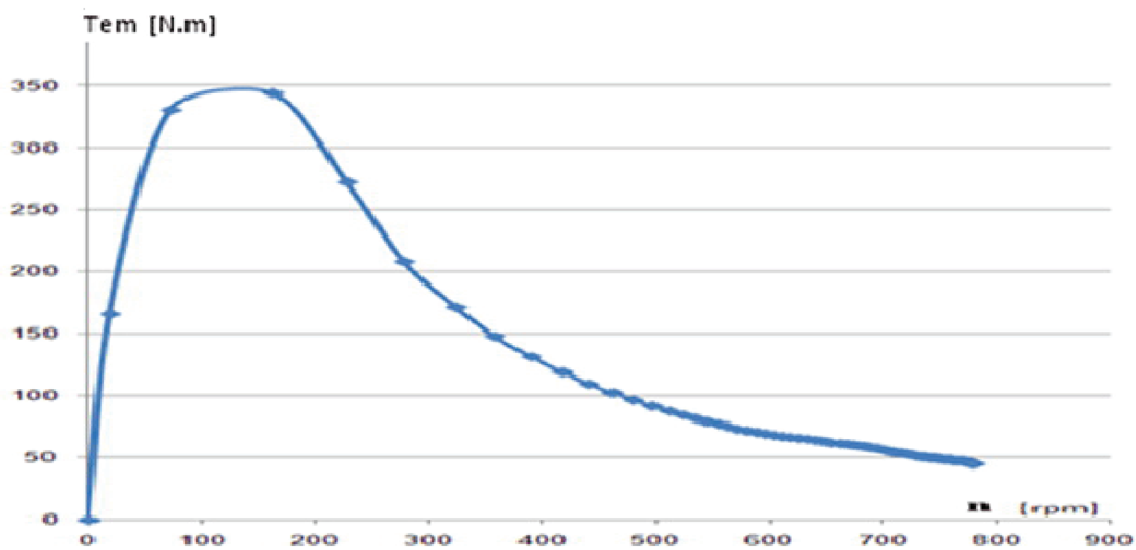

Fig.9 variation of active torque with rotating speed of motor at 34 N.m resistive torque

Fig. 10 and Fig.11 show the variation in time of the rotating speed and the active torque of DC Series Motor, when a total resistive torque of 17 N.m is applied.
Fig.10 shows the variation in time of the rotating speed of DC Series Motor, when 17N.m resistive torque applied. The rotating speed in this test varies very smoothly from 0 to 820 rpm.
The fig.11 shows the variation of the active torque with the rotating speed of the motor, when 17N.mresistivetorqueis applied. In this fig.11, it can be observed that the active torque reaches a maximum starting value of 320 N.m, and stabilizes at 17 N.m, after a transient period of 1.2 sec.

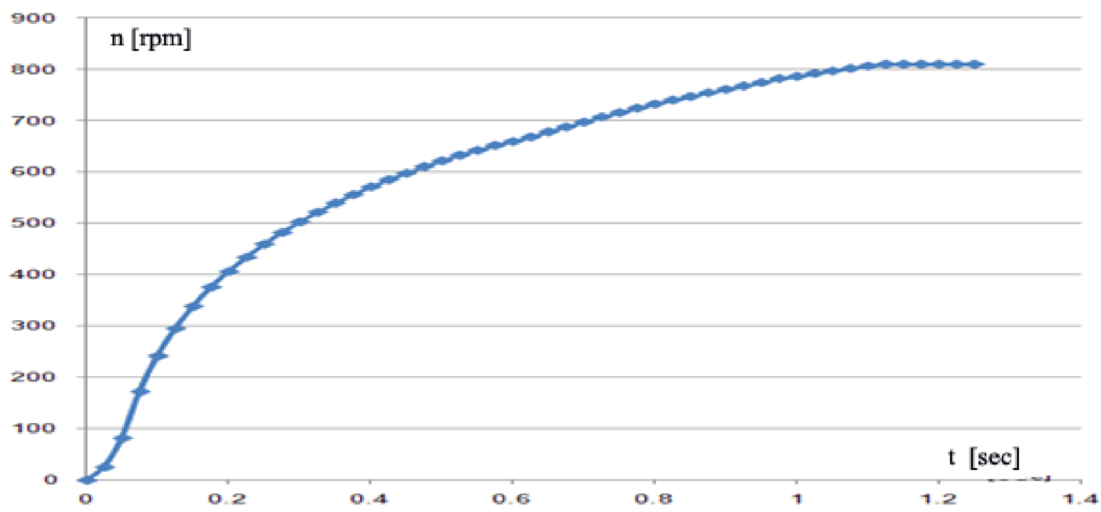

Fig.10 variation in time of active torque of DC Series Motor at17N.m resistive torque

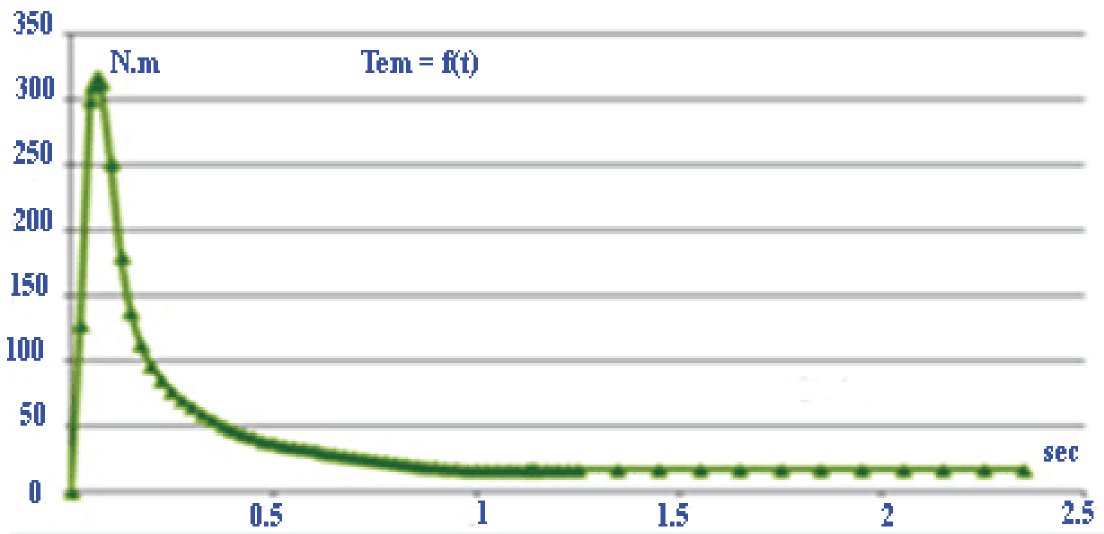

Fig.11 variation in time of active torque of DC Series Motor at 17 N.m resistive torque

It can be observed that active torque reach maximum starting value of 320 N.m and stabilize on 17 N.m after a transient period of 1.2 sec.

Fig.12 presents the variation of the active torque with the rotating speed of the motor, when 17N.m resistive torque is applied.

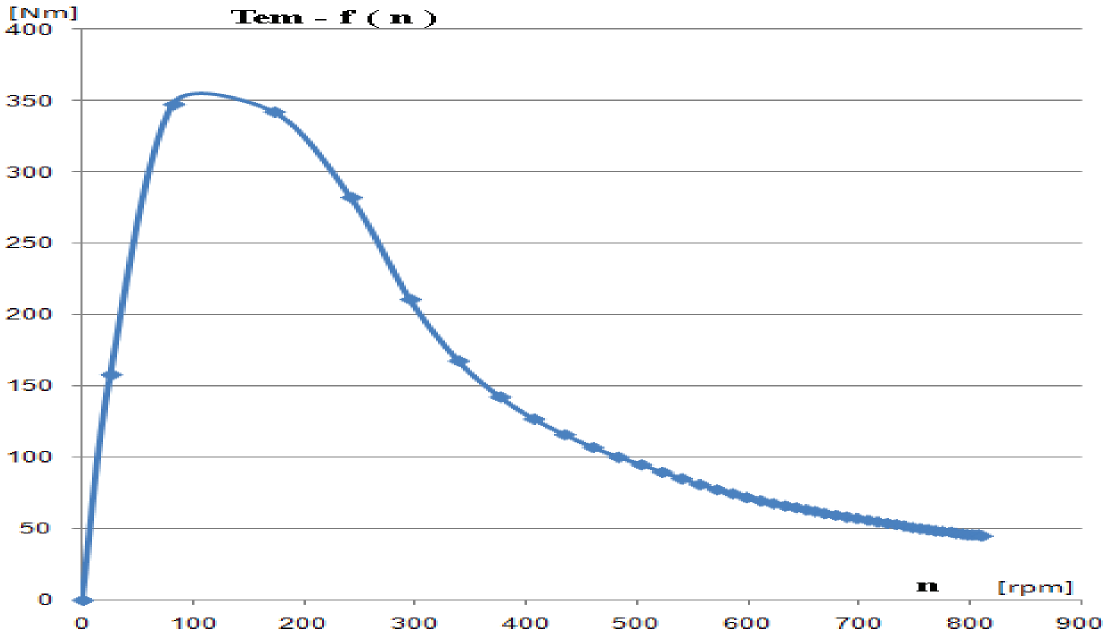

Fig. 12 variation of active torque with rotating speed of motor at 17N.m resistive torque

The test results of this practical case were put together in a chart for the rotating speed (Fig.13), and another chart for the active torque (Fig.14), at different resistive loads.

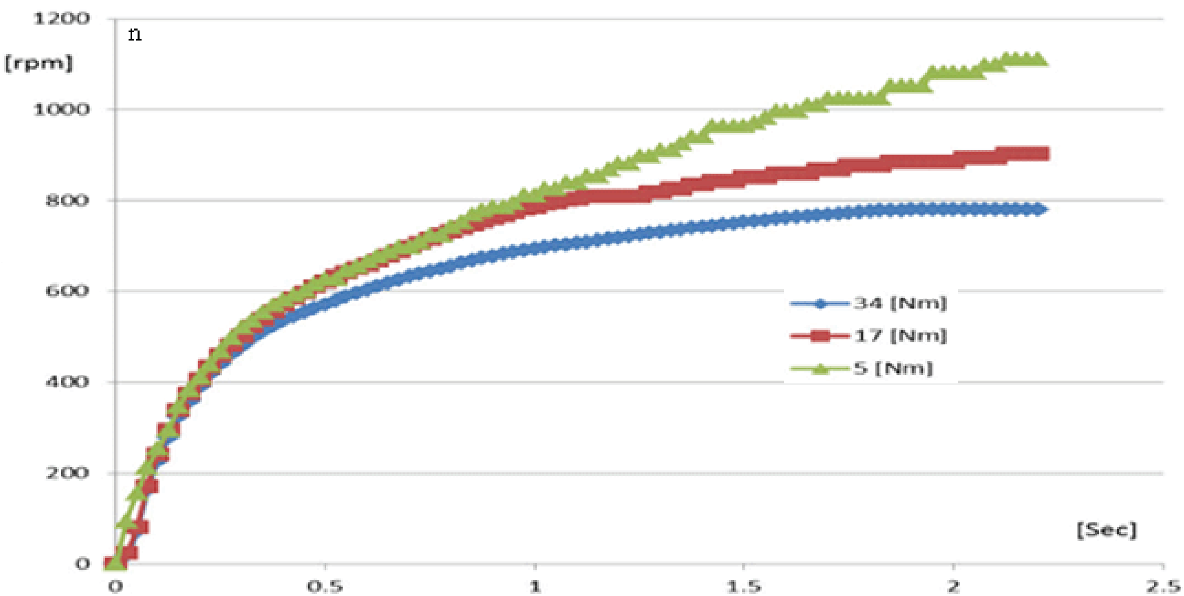

Fig.13 Variation in time of rotating speed of DC Series Motor at different loads

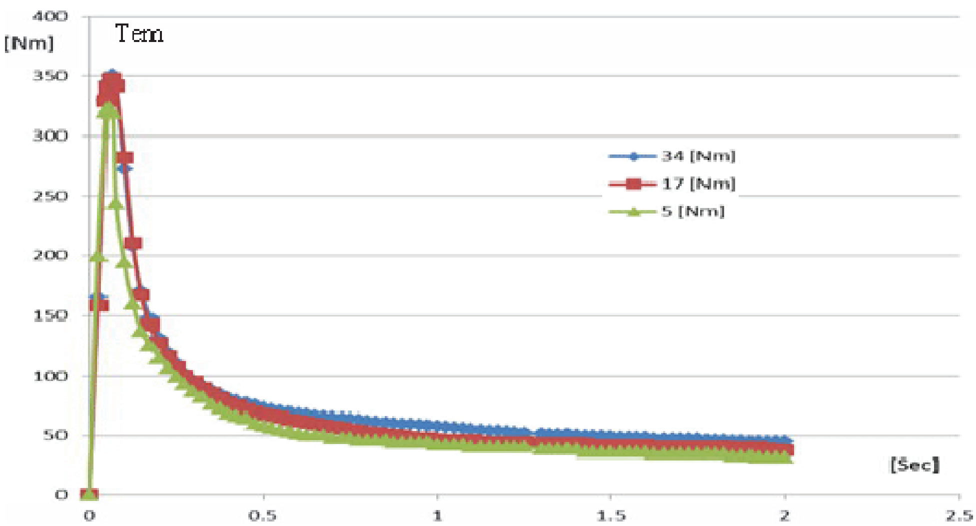

Fig.14 Variation in time of active torque of DC Series Motor at different loads

3 -2 Testing the DC Series Motor to simulate running the car from standing position, accelerating to reach a certain speed and then decelerate till stop:

Fig.15 shows the variation in time of the torque of DC Series Motor, when a load torque of 34N.m, equal to 100% of the nominal torque of DC Series Motor, is applied. The transient period, till the active torque and rotation became stable, is 1 sec.

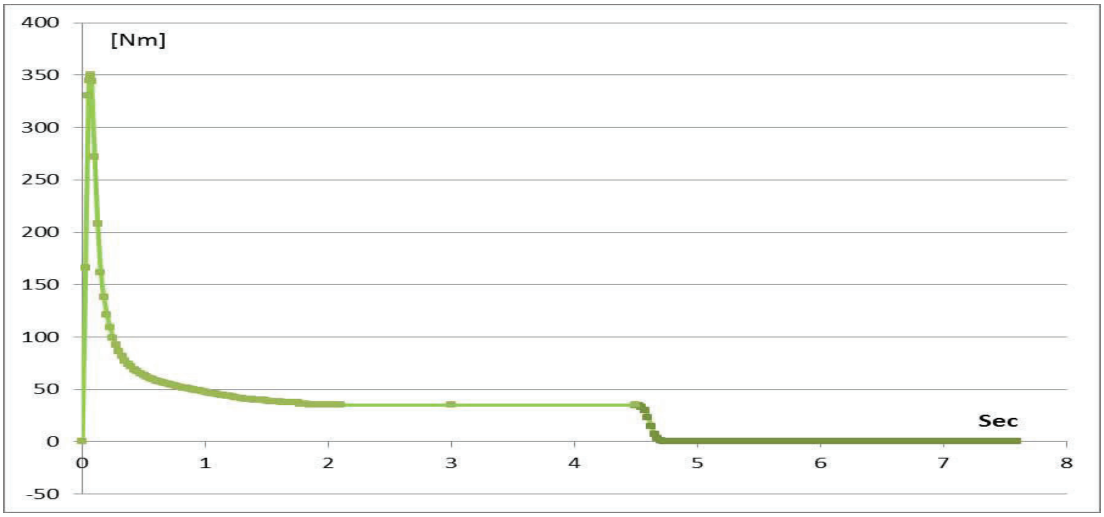

Fig. 15 Variation in time of torque of DC Series Motor at 34 N.m resistive torques

It can be noticed that the value of starting torque reached 350N.m, comparing with the active torque 34 N.m, which locates within the accepted limits of the tested DC Series Motor characteristics.
By reducing the rotating speed till zero, DC Series Motor can operate in the case of energy recovering, as the absorbed current becomes negative and can be used to charge the batteries.

InFig.16, the variations in time of the rotating speed of DC Series Motor are given, when a load torque of 34 N.m (100% of the nominal torque of DC Series Motor) is applied.

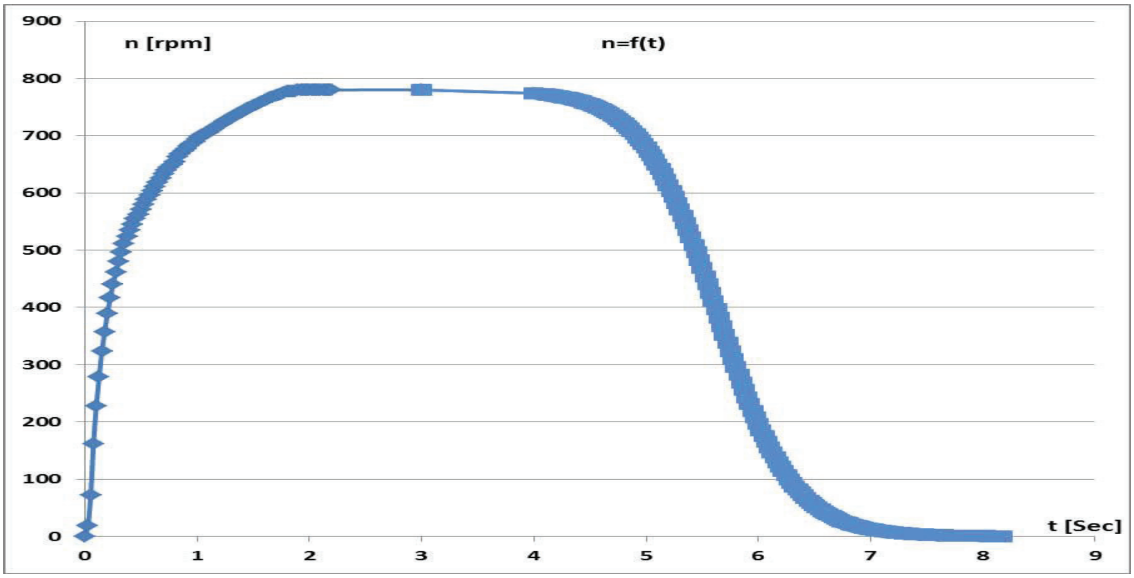

Fig. 16 Variation in time of rotating speed of DC Series Motor at 34 N.m resistive torques

Fig.17 shows variation in time of torque of DC Series Motor when a load torque of 17 N.m equal to 50% of the nominal torque of DC Series Motor is applied. The transient period till active torque became stable is 1 sec.

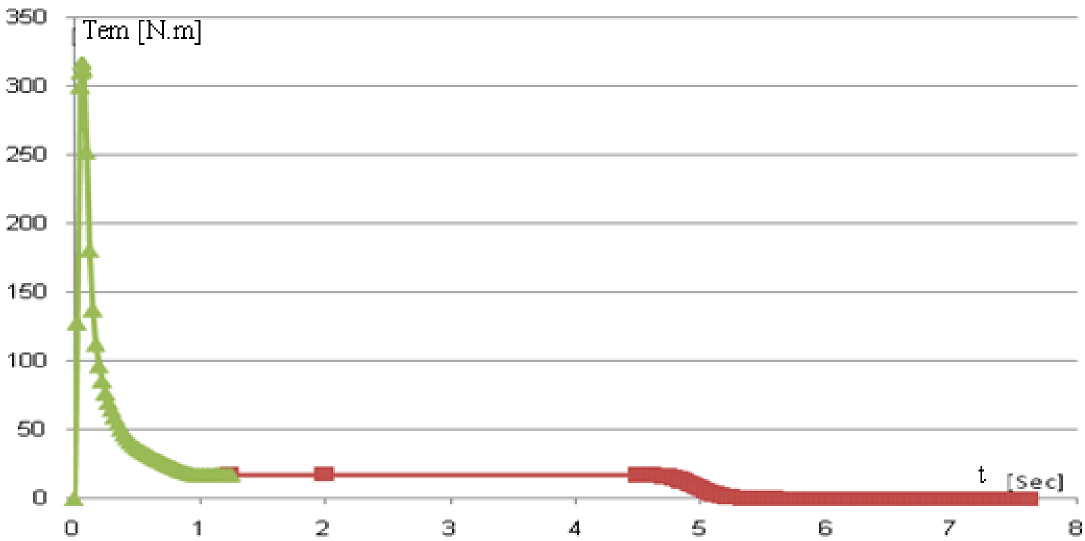

Fig.17 Variation in time of torque of DC Series Motor at 17 N.m resistive torques

In Fig.18, the variations in time of the rotating speed of DC Series Motor are given, when a load torque of 17 N.m (50% of the nominal torque of DC Series Motor) is applied.

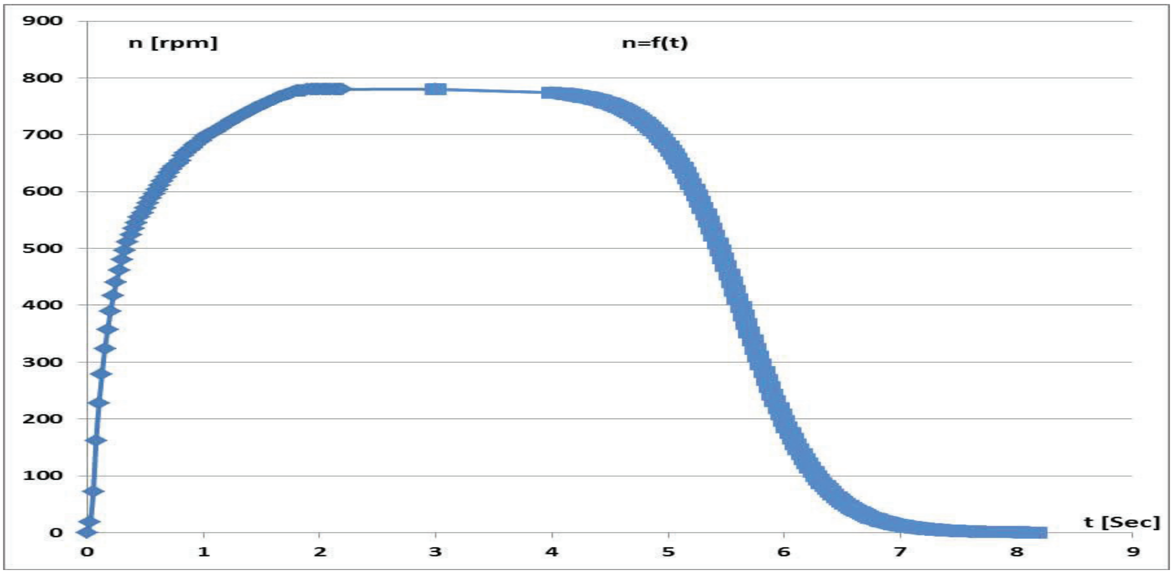

Fig. 18 Variation in time of rotating speed of DC Series Motor at 17 N.m resistive torque

By reducing the rotating speed till zero, DC Series Motor can operate in the case of energy recovering, as the absorbed current becomes negative and can be used to charge the batteries.

In Fig.19, the variations in time of the active torque of DC Series Motor are given, when a load torque of 5 N.m (15% of the nominal torque of DC Series Motor) is applied. The transient period lasts for 3 sec., till the active torque stabilizes.

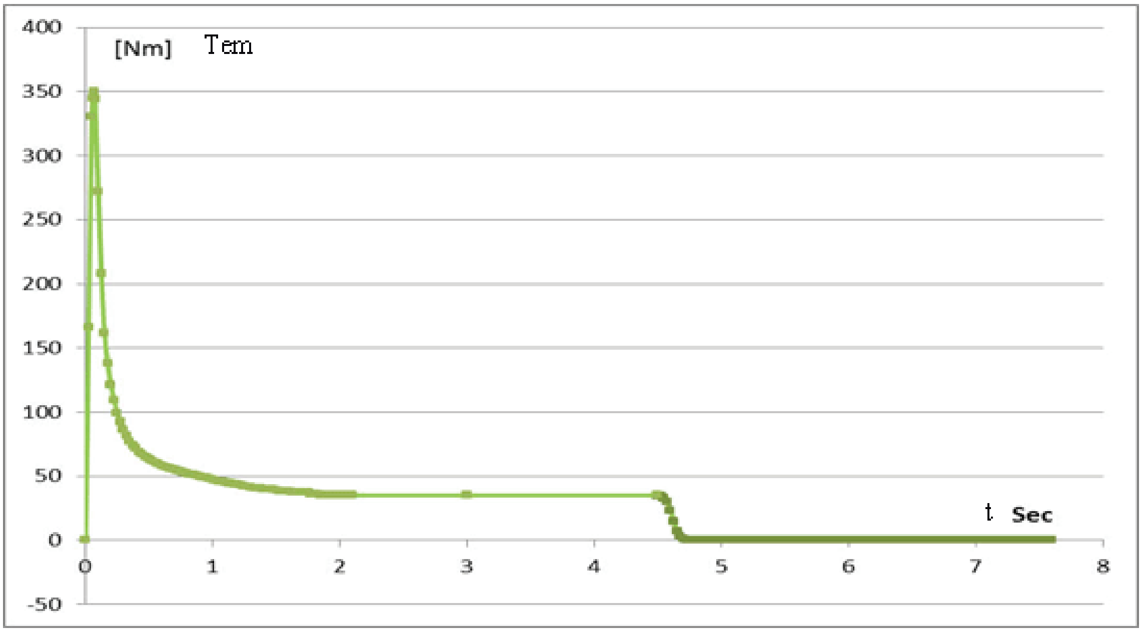

Fig.19 Variation in time of torque of DC Series Motor at 5N.m resistive torque

In Fig.20, the variations in time of the rotating speed of DC Series Motor are given, when a load torque of 5 N.m (15% of the nominal torque of DC Series Motor) is applied.

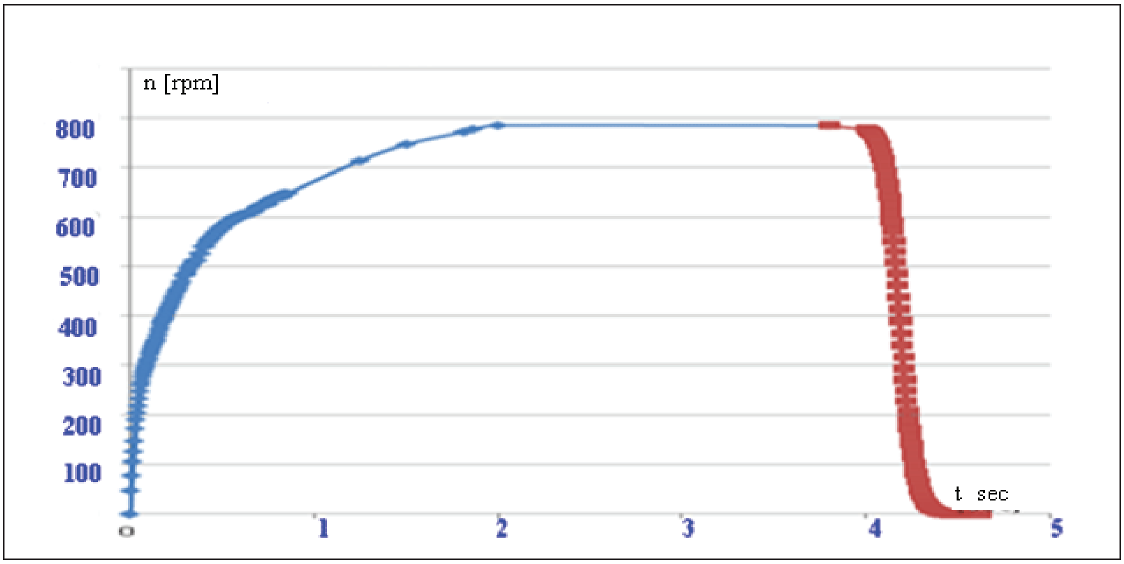

Fig.20 variations in time of rotating speed of DC Series Motor at a load torque of 5 N.m

4. Conclusions:

The practical tests results show that the tested DC Series Motor is best to be used in electric traction. The values of maximum active torque are very high, when different load torques is applied. The DC Series Motor can easily drive the car with its loads.
When rotating speed of DC Series Motor is reduced till zero during the car running, DC Series Motor can operate as generator to regenerate energy, but this needs special additional electric circuits. This regeneration is fully used in the electric trains and diesel electric trains and can be used to charge the batteries or supplied to the electric network.
The behavior of the tested DC Series Motor in all proposed running cases of the car is very satisfactory, but it loses in favor of 3-pahase Induction Motor, being the induction motor less expensive, less complicated construction and less volume and weight.

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